

THIRD EDITION

NYSORA
CONTINUING MEDICAL EDUCATION



HADZIC'S PERIPHERAL NERVE BLOCKS

AND ANATOMY FOR
ULTRASOUND-GUIDED
REGIONAL ANESTHESIA

ADMIR HADZIC

EDITION EDITORS: ANA M. LOPEZ

ANGELA LUCIA BALOCCO • CATHERINE VANDEPITTE

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NEW YORK SCHOOL OF REGIONAL ANESTHESIA

Hadzic's Peripheral Nerve Blocks and Anatomy for Ultrasound-Guided Regional Anesthesia

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NEW YORK SCHOOL OF REGIONAL ANESTHESIA

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THIRD EDITION

Editors

Ana M. Lopez, MD, PhD, DESA

Consultant Anesthesiology, Ziekenhuis Oost-Limburg (ZOL), Genk, Belgium

Angela Lucia Balocco, MD

Research Associate NYSORA, The New York School of Regional Anesthesia
Anesthesia Resident, Ziekenhuis Oost-Limburg (ZOL), Genk, Belgium

Catherine Vandepitte, MD, PhD

Research Associate NYSORA, The New York School of Regional Anesthesia
Consultant Anesthesiology, Ziekenhuis Oost-Limburg (ZOL), Genk, Belgium

Admir Hadzic, MD, PhD

Director NYSORA, The New York School of Regional Anesthesia
Consultant Anesthesiology, Ziekenhuis Oost-Limburg (ZOL), Genk, Belgium
Visiting Professor, Department of Anesthesiology, Katholieke Universiteit Leuven (KUL), Belgium
Honorary Professor, University of Ljubljana, Slovenia
Doctor Honoris Causa, Karol Marcinkowski University of Medical Sciences, Poznan, Poland



New York Chicago San Francisco Lisbon London Madrid Mexico City
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DEDICATION

We dedicate this book to Jerry Vloka, MD, PhD
in recognition of his pioneering contributions to regional anesthesia
and immense inspiration for generations of students
and scholars of anesthesiology.



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CONTENTS

Contributors	ix	15. Infraclavicular Brachial Plexus Block	161	
Foreword	xiii	16. Costoclavicular Brachial Plexus Block	169	
Acknowledgments	xv	17. Axillary Brachial Plexus Block	177	
SECTION 1				
FOUNDATIONS				
1. Functional Regional Anesthesia Anatomy	3	18. Blocks for Analgesia of the Shoulder: Phrenic Nerve Sparing Blocks	185	
2. Local Anesthetics: Clinical Pharmacology and Selection	33	19. Blocks About the Elbow	195	
3. Equipment for Peripheral Nerve Blocks	47	20. Wrist Block	205	
4. Electrical Nerve Stimulation	57	SECTION 4		
5. Optimizing Ultrasound Image	67	LOWER EXTREMITY BLOCKS		
6. Monitoring and Documentation in Regional Anesthesia	75	21. Lumbar Plexus Block	217	
7. Indications for Peripheral Nerve Blocks	89	22. Fascia Iliaca Block	229	
8. Continuous Peripheral Nerve Blocks	101	23. Blocks for Hip Analgesia	239	
9. Local Anesthetic Systemic Toxicity and Allergy to Local Anesthetics	107	24. Femoral Nerve Block	247	
10. Neurologic Complications of Peripheral Nerve Blocks	117	25. Subsartorial Blocks: Saphenous Nerve, Adductor Canal, and Femoral Triangle Blocks	255	
11. Preparation for Regional Anesthesia and Perioperative Management	123	26. Lateral Femoral Cutaneous Nerve Block	265	
SECTION 2				
HEAD AND NECK BLOCKS				
12. Cervical Plexus Block	131	27. Obturator Nerve Block	271	
SECTION 3				
UPPER EXTREMITY BLOCKS				
13. Interscalene Brachial Plexus Block	143	28. Proximal Sciatic Nerve Block	281	
14. Supraclavicular Brachial Plexus Block	153	29. Popliteal Sciatic Block	291	
SECTION 4				
LOWER EXTREMITY BLOCKS				
SECTION 5				
TRUNK AND ABDOMINAL WALL BLOCKS				
21. Lumbar Plexus Block				217
22. Fascia Iliaca Block				229
23. Blocks for Hip Analgesia				239
24. Femoral Nerve Block				247
25. Subsartorial Blocks: Saphenous Nerve, Adductor Canal, and Femoral Triangle Blocks				255
26. Lateral Femoral Cutaneous Nerve Block				265
27. Obturator Nerve Block				271
28. Proximal Sciatic Nerve Block				281
29. Popliteal Sciatic Block				291
30. Genicular Nerves Block				299
31. iPACK Block				305
32. Ankle Block				313
33. Intercostal Nerve Block				325
34. Pectoral Nerves Block				333

35. Serratus Plane Block	341	39. Rectus Sheath Block	379
36. Paravertebral Block	349	40. Quadratus Lumborum Blocks	385
37. Erector Spinae Plane Block	359		
38. Transversus Abdominis Plane Blocks	367	Index	395

CONTRIBUTORS

David Alvarez, MD

Department of Anesthesiology
Hospital Universitari de Bellvitge
Barcelona, Spain
(Chapter 20)

Angela Lucia Balocco, MD

Department of Anesthesiology
Ziekenhuis Oost-Limburg
Genk, Belgium
(Chapters 9, 11, 19, 31, 35, 37, 38, 39, and 40)

Jonas Bruggen, MD

Department of Anesthesiology
UZ Leuven
Leuven, Belgium
(Chapter 21)

Robbert Buck, MD

Department of Anesthesiology
UZ Antwerpen
Antwerpen, Belgium
(Chapter 12)

Eveline Claes, MD

Department of Anesthesiology
AZ Diest
Diest, Belgium
(Chapter 10)

Tomás Cuñat, MD, DESA

Department of Anesthesiology
Hospital Clinic de Barcelona
Barcelona, Spain
(Chapter 30)

Lotte Cuyx, MD

Department of Anesthesiology
UZ Leuven
Leuven, Belgium
(Chapter 38)

Olivier De Fré, MD

Anesthesiology Department
AZ Herentals
Herentals, Belgium
(Chapter 2)

Javier Domenech de la Lastra, MD, DESA

Department of Anesthesiology
Hospital Clinic de Barcelona
Barcelona, Spain
(Chapter 16)

Robin De Meirsman, MD

Department of Anesthesiology
UZ Leuven
Leuven, Belgium
(Chapter 34)

Dimitri Dylst, MD

Department of Anesthesiology
Ziekenhuis Oost-Limburg
Genk, Belgium
(Chapter 17)

Christopher J. Edwards, MD

Department of Anesthesiology
Wake Forest Baptist Medical Center
Winston Salem, North Carolina
United States of America
(Chapter 36)

Gert-Jan Eerdeken, MD

Department of Anesthesiology
UZ Leuven
Leuven, Belgium
(Chapters 17 and 40)

Victor Frutos, MD

Department of Anesthesiology and Pain Clinics
Hospital Universitari Germans Trias i Pujol
Badalona, Spain
(Chapter 1)

Jeff Gadsden, MD

Department of Anesthesiology
Duke University Hospital
Durham, North Carolina
United States of America
(Chapter 10)

Levin Garip, MD

Department of Anesthesiology
UZ Leuven
Leuven, Belgium
(Chapter 2)

Admir Hadzic, MD, PhD

Director, The New York School of Regional Anesthesia
New York, United States of America
Department of Anesthesiology
Ziekenhuis Oost-Limburg
Genk, Belgium
(Chapters 3, 4, 10, and 11)

Rawad Hamzi, MD

Department of Anesthesia and Pain Management
Wake Forest Baptist Medical Center
Winston Salem, North Carolina,
United States of America
(Chapter 33)

Tyler Heijnen, MD

Department of Anesthesiology
Ziekenhuis Oost-Limburg
Genk, Belgium
(Chapter 18)

Jelena Heirbaut, MD

Department of Anesthesiology
UZ Antwerpen
Antwerpen, Belgium
(Chapter 4)

Jore Hendrikx, MD

Department of Anesthesiology
UZ Leuven
Leuven, Belgium
(Chapter 31)

Lotte Hendrix, MD

Department of Anesthesiology
UZ Leuven
Leuven, Belgium
(Chapter 13)

Daryl S. Henshaw, MD

Department of Anesthesiology and Pain Management
Wake Forest Baptist Medical Center
Winston Salem, North Carolina
United States of America
(Chapter 36)

Peter Hulsbosch, MD

Department of Anesthesiology
Regionaal Ziekenhuis Heilig Hart
Leuven, Belgium
(Chapter 15)

J. Douglas Jaffe, MD

Department of Anesthesiology and Pain Management
Wake Forest Baptist Medical Center
Winston Salem, North Carolina
United States of America
(Chapter 33)

Leen Janssen, MD

Department of Anesthesiology
UZ Antwerpen
Antwerpen, Belgium
(Chapter 5)

Manoj K. Karmakar, MD

Director of Pediatric Anesthesia
Chinese University of Hong Kong
Prince of Wales Hospital
Sha Tin, Hong Kong, China
(Chapter 21)

Bram Keunen, MD

Department of Anesthesiology
Ziekenhuis Oost-Limburg
Genk, Belgium
(Chapter 15)

Samantha Kransingh, FCA, FANZCA

South Canterbury District Health Board
Timaru, New Zealand
(Chapters 5 and 22)

Queenayda A. D. Kroon, MD

Department of Anesthesia and Pain Management
University Medical Centre Maastricht
Maastricht, The Netherlands
(Chapter 33)

Annelies Langenaeken, MD

Department of Anesthesiology
UZ Leuven
Leuven, Belgium
(Chapter 29)

Raphaël Lapré, MD

Department of Anesthesiology
AZ Rivierenland
Reet, Belgium
(Chapter 2)

Ana Lopez, MD, PhD

Department of Anesthesiology
Ziekenhuis Oost-Limburg
Genk, Belgium
(Chapters 1, 11, 12, 16, 18, 20, 21, and 32)

Sofie Louage, MD

Department of Anesthesiology
AZ Glorieux
Ronse, Belgium
(Chapters 27, 28, and 29)

Leander Mancel, MD

Department of Anesthesiology
UZ Leuven
Leuven, Belgium
(Chapter 6)

Berend Marcus, MD

Department of Anesthesiology
UZ Leuven
Leuven, Belgium
(Chapter 7)

Evi Mellebeek, MD

Department of Anesthesiology
Ziekenhuis Oost-Limburg
Genk, Belgium
(Chapter 24)

Felipe Muñoz-Leyva, MD

Department of Anesthesia and Pain Management
University Health Network, University of Toronto,
Toronto Western Hospital
Toronto, Ontario, Canada
(Chapters 9 and 37)

Gwendolyne Peeters, MD

Department of Anesthesiology
UZ Gent
Gent, Belgium
(Chapter 9)

Xavier Sala-Blanch, MD

Department of Anesthesiology
Hospital Clinic de Barcelona
Barcelona, Spain
(Chapters 1 and 23)

Amar Salti, MD, EDRA

Department of Anesthesia and Pain Medicine
Sheikh Khalifa Medical City
Abu Dhabi, United Arab Emirates
(Chapter 22 and 27)

Ruben Schreurs, MD

Department of Anesthesiology
Ziekenhuis Oost-Limburg
Genk, Belgium
(Chapter 25)

Jeroen Smet, MD

Department of Anesthesiology
UZ Gent
Gent, Belgium
(Chapter 3)

Filiep Soetens, MD

Department of Anesthesiology
AZ Turnhout
Turnhout, Belgium
(Chapters 2 and 9)

Sam Van Boxstael, MD

Department of Anesthesiology
Ziekenhuis Oost-Limburg
Genk, Belgium
(Chapters 24, 25, and 26)

Imré Van Herreweghe, MD

Department of Anesthesiology
AZ Turnhout
Turnhout, Belgium
(Chapters 2 and 7)

Astrid Van Lantschoot, MD

Department of Anesthesiology
Ziekenhuis Oost-Limburg
Genk, Belgium
(Chapters 34 and 35)

Kathleen Van Loon, MD

Department of Anesthesiology
UZ Leuven
Leuven, Belgium
(Chapter 9)

Jill Vanhaeren, MSc

Research Associate
The New York School of Regional Anesthesia
New York, United States of America
(Chapter 39)

Catherine Vandepitte, MD, PhD

Department of Anesthesiology
Ziekenhuis Oost-Limburg
Genk, Belgium
(Chapters 6, 8, 11, 15, 17, 19, and 28)

Stefanie Vanhoenacker, MD

Department of Anesthesiology
Sint-Jozefskliniek Izegem
Izegem, Belgium
(Chapter 14)

Thibaut Vanneste, MD

Department of Anesthesiology
Ziekenhuis Oost-Limburg
Genk, Belgium
(Chapters 13, 14, 23, and 30)

Rob Vervoort, MD

Department of Anesthesiology

UZ Leuven

Leuven, Belgium

(Chapter 8)

Daquan Xu

Associate Researcher

The New York School of Regional Anesthesia

New York, United States of America

(Chapter 5)

FOREWORD

The third edition of this standard textbook on ultrasound nerve blocks is released during a unique period in human history. The COVID-19 pandemic and the threats that the disease poses to both patients and healthcare workers have substantially changed perioperative practice. During the pandemic, regional anesthesia was established as the preferred method over general anesthesia whenever possible. Nerve blocks preserve respiratory function and avoid aerosolization during intubation and extubation and, hence, viral transmission to other patients and healthcare workers. As an example, the use of nerve blocks as the preferred surgical anesthesia method during the pandemic allowed many limb surgeries to be carried out with decreased exposure to healthcare workers and less burden on post-anesthesia care units (PACUs) and utilization of hospital beds. With regional anesthesia, patients can leave acute postoperative care facilities faster and avoid admission to the limited hospitalization beds. In our center, using regional anesthesia and nerve blocks as the main anesthetic choice allowed elective orthopedic surgery in many patients.

The use of ultrasound-guided local regional anesthesia (LRA) has increased exponentially in the last few years. The traditional techniques have been refined and a number of new approaches have been devised to better suit the evolving clinical practice. Nerve blocks are an essential component of multimodal analgesia in enhanced recovery after surgery (ERAS) protocols. Their use enhances analgesia and reduces or eliminates the use of opioids in the postoperative period. Some traditional nerve block techniques have been substituted by more selective techniques to minimize motor block and facilitate early rehabilitation and recovery. New ultrasound-guided fascial plane techniques, distal nerve blocks, and selective periarticular injections also are increasingly being used to yield a better balance between efficacy, simplicity, safety, and sensory-motor block ratio.

This third edition of NYSORA's textbook is substantially updated and revised to include the many new developments in regional anesthesia and trends in clinical practice. The new edition features entirely new artwork, new clinical images, and new fascial plane and infiltration techniques. All in all, some 500 new algorithms, illustrations, ultrasound images, clinical photographs, and cognitive aids were included to facilitate learning. In addition to anesthesiologists, the highly didactic and organized technique descriptions and functional anatomy principles will be valuable to all anesthesia providers, acute and chronic pain specialists, as well as interventional pain, musculoskeletal medicine, and emergency department physicians.

NYSORA's Reverse Ultrasound Anatomy™ (RUA) images feature functional anatomy or block techniques with clear instructions on the principles and goals of each given technique. These cognitive aids entailed countless hours of work and collaboration between NYSORA's creative and editorial teams to develop highly didactic creatives that facilitate understanding of the anatomy, fascial planes, and principles of nerve blockade. RUA helps students memorize sonoanatomy patterns, which is essential for ultrasound imaging. The knowledge of the sonoanatomy patterns substantially increases ultrasound proficiency and skills retention. Whenever applicable, clinical images of the patient's position, ultrasound transducer placement, and anatomical detail are featured. Recent relevant literature was added to the "Suggested Reading" for readers who like to explore the original sources of the information presented. We chose this approach in an effort to provide the most practical, pragmatic information and relieve the content from massive literature citations.

Readers should be advised that this book is not meant to be an encyclopedic listing of all techniques and their variations. Rather, our textbook should be viewed as a compendium of well-established knowledge, didactically organized for learning, and transferring knowledge to students of anesthesiology. With this approach, the textbook aims to help standardize, and implement well-established techniques, indications, pharmacology, monitoring, and the documentation of nerve blocks. Instead of burdening the reader with experimental block techniques with unproven clinical benefit, we aimed to include the most clinically useful nerve block, fascial, and infiltration techniques with proven efficacy and clinical applicability. Information about perioperative management and local anesthetic toxicity treatment was also added, and/or fully revised. Because patients commonly present with a vague history of allergy to local anesthetics, the new edition also features highly practical algorithms to facilitate decision-making and management of allergy to local anesthetics.

We are confident that this textbook will continue to be one of the primary resources on peripheral nerve blocks in medical practices worldwide.

Sincerely,

Drs Hadzic, Lopez, Balocco, and Vandepitte

Free access to online videos at www.accessanesthesiology.com. Search for this title in the library and select "View All Videos" in the Multimedia widget on the landing page of the book.

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This book would not be possible without the extraordinary people who contributed their time and talent and undying commitment to create an educational masterpiece. Many thanks to Drs Ana Lopez (senior editor), Angela Lucia Balocco, and Catherine Vandepitte, the third edition editors. Their combination of commitment, knowledge, research, and clinical expertise is apparent on every page of this book.

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Many thanks to all top fellows in regional anesthesia. These young, bright doctors contribute immense value to our teaching mission, and carry on the mission of national ambassadors of regional anesthesia after graduation. Big gratitude to our anesthesia residents who rotate through our service from their mothership Universities: Leuven (KUL), Gent, Antwerp, and others.

Our orthopedic surgery department is by all means one of the best in Europe and beyond. Made up of ultra high-achievers; physicians of national, Olympic, and professional

football teams; innovators; and above all incredibly skilled and passionate surgeons. It has been an absolute pleasure building the orthopedic anesthesia service with you. A short glimpse at the website of the department of orthopedic surgery at ZOL is sufficient to get a sense that NYSORA-EUROPE at ZOL is flanked by true giants of orthopedic surgery (<https://www.zol.be/raadplegingen/orthopedie>).

Thank you to the NYSORA International Team: Pat Pokorny (UK), Kusum Dubey (New Delhi), Katherine Hughey-Kubena (USA), Elvira Karovic, Medina Brajkovic, Ismar Ruznjic (B&H), Nenad Markovic (SER), Jill Vanhaeren, and Greet van Meir (BE). This is an incredible team of NYSORA's go-getters.

Thank you to NYSORA's illustrator Ismar Ruznjic for the new-style illustrations and artwork he imparted to this edition. Ismar has grown with NYSORA to become one of the world's very best anatomy illustrators.

A big thank you to our designer and 3-D maestro, Nenad Markovic, an ultimate perfectionist, whose eye has been constructively critical to many artistic and stylistic aspects of this book, and NYSORA's content at large.

Finally, a huge thanks to all the contributors to this book, as there have been quite a few. Such a volume, packed with so much anatomical information, can always have hidden errors. We have relied on our stellar contributors to detect and correct them wherever possible. However, should the readers find any that we have missed that require correction, please forward them to info@nysora.com. We vouch to improve upon them and thank you immensely in advance for your feedback.

Many thanks to all,

Editors

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Foundations

Chapter 1	Functional Regional Anesthesia Anatomy	3
Chapter 2	Local Anesthetics: Clinical Pharmacology and Rational Selection	33
Chapter 3	Equipment for Peripheral Nerve Blocks	47
Chapter 4	Electrical Nerve Stimulation	57
Chapter 5	Optimizing Ultrasound Image	67
Chapter 6	Monitoring and Documentation in Regional Anesthesia	75
Chapter 7	Indications for Peripheral Nerve Blocks	89
Chapter 8	Continuous Peripheral Nerve Blocks	101
Chapter 9	Local Anesthetic Systemic Toxicity and Allergy to Local Anesthetics	107
Chapter 10	Neurologic Complications of Peripheral Nerve Blocks	117
Chapter 11	Preparation for Regional Anesthesia and Perioperative Management	123

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1

Functional Regional Anesthesia Anatomy

Knowledge of anatomy is essential for the practice of regional anesthesia and ultrasound-guided regional anesthesia procedures. This chapter provides a concise overview of the essential functional anatomy necessary for the implementation of traditional and ultrasound-guided regional anesthesia techniques. **Figure 1-1** demonstrates the anatomical planes and directions used as a conventional approach throughout the book.

Anatomy of Peripheral Nerves

The neuron is the basic functional unit responsible for nerve conduction. Neurons are the longest cells in the body, often as long as 1 meter. Most neurons have a limited ability to repair after injury. Advances in the understanding of the neurobiology of nerve regeneration and experimental advances in

biotechnology may eventually result in development of the strategies to promote axonal growth and reduce neuronal death.

A typical neuron consists of a cell body (soma) with a large nucleus. The cell body is attached to several branching processes, called dendrites, and a single axon (**Figure 1-2**). Dendrites receive incoming messages, whereas single axons per neuron conduct outgoing messages. In peripheral nerves, axons are long and slender; they are often referred to as nerve fibers.

Connective Tissue

The peripheral nerve is composed of three types of fibers: (1) somatosensory or afferent nerves, (2) motor or efferent nerves, and (3) autonomic nerves. In a peripheral

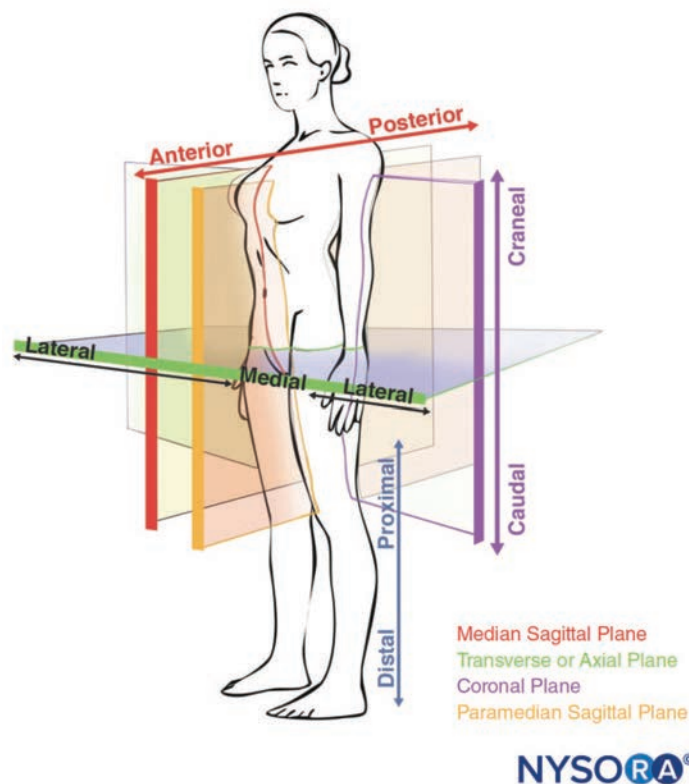


FIGURE 1-1. Conventional body planes and directions. Red, sagittal; orange, sagittal paramedian; green, transverse; and purple, coronal or axial.

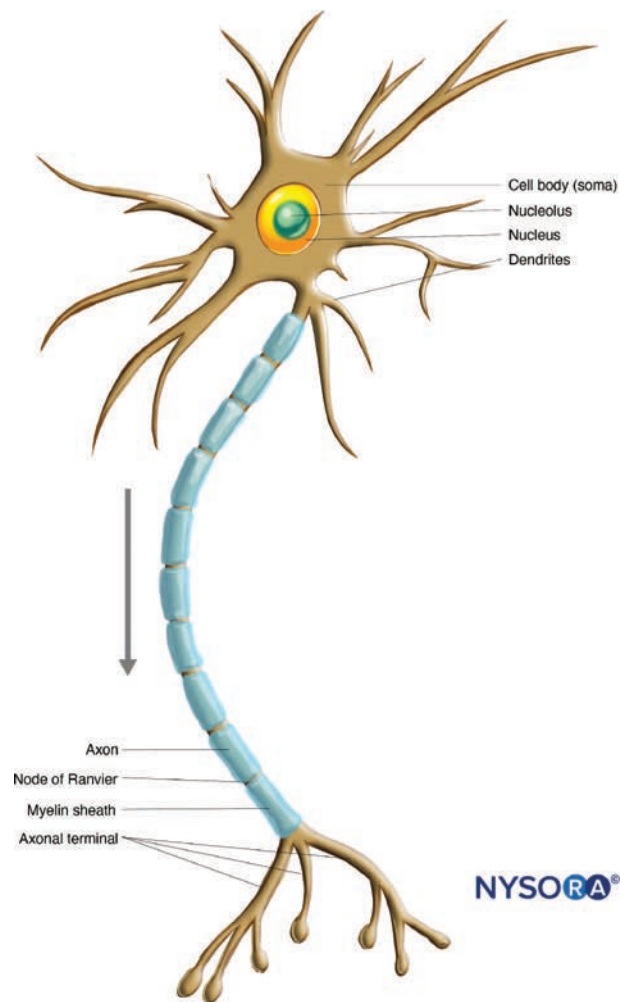


FIGURE 1-2. Composition of the neuron.

nerve ([Figure 1-3](#)), individual axons are enveloped in a loose and delicate connective tissue, the **endoneurium**. Groups of axons are arranged within a bundle (nerve fascicle) surrounded by the **perineurium**. The perineurium imparts mechanical strength to the peripheral nerve and functions as a diffusion barrier to the fascicle, isolating the endoneurial space and preserving the ionic milieu of the axon. At each branching point, the perineurium splits with the fascicle. The fascicles, in turn, are embedded in loose connective tissue called the **interfascicular epineurium**, which contains adipose tissue, fibroblasts, mastocytes, blood vessels, and lymphatics. The outer layer surrounding the nerve is the **epineurium**, a denser collagenous tissue that protects the nerve. The **paraneurium** consists of loose connective tissue that holds a stable relationship between adjacent

structures filling the space in between them, such as the neurovascular bundles of intermuscular septae. This tissue contributes to the functional mobility of nerves during joint and muscular movement.

Of note, the fascicular bundles are not continuous throughout the peripheral nerve but divide and anastomose with one another as frequently as every few millimeters ([Figure 1-4](#)). This arrangement of peripheral nerves helps to explain why intraneural injections, which disrupt this organization, may result in disastrous consequences as opposed to clean needle nerve cuts, which heal more readily. In the vicinity of joints, the fascicles are thinner, more numerous, and are likely surrounded by a greater amount of connective tissue, which reduces the vulnerability of the fascicles to pressure and stretching caused by movement.

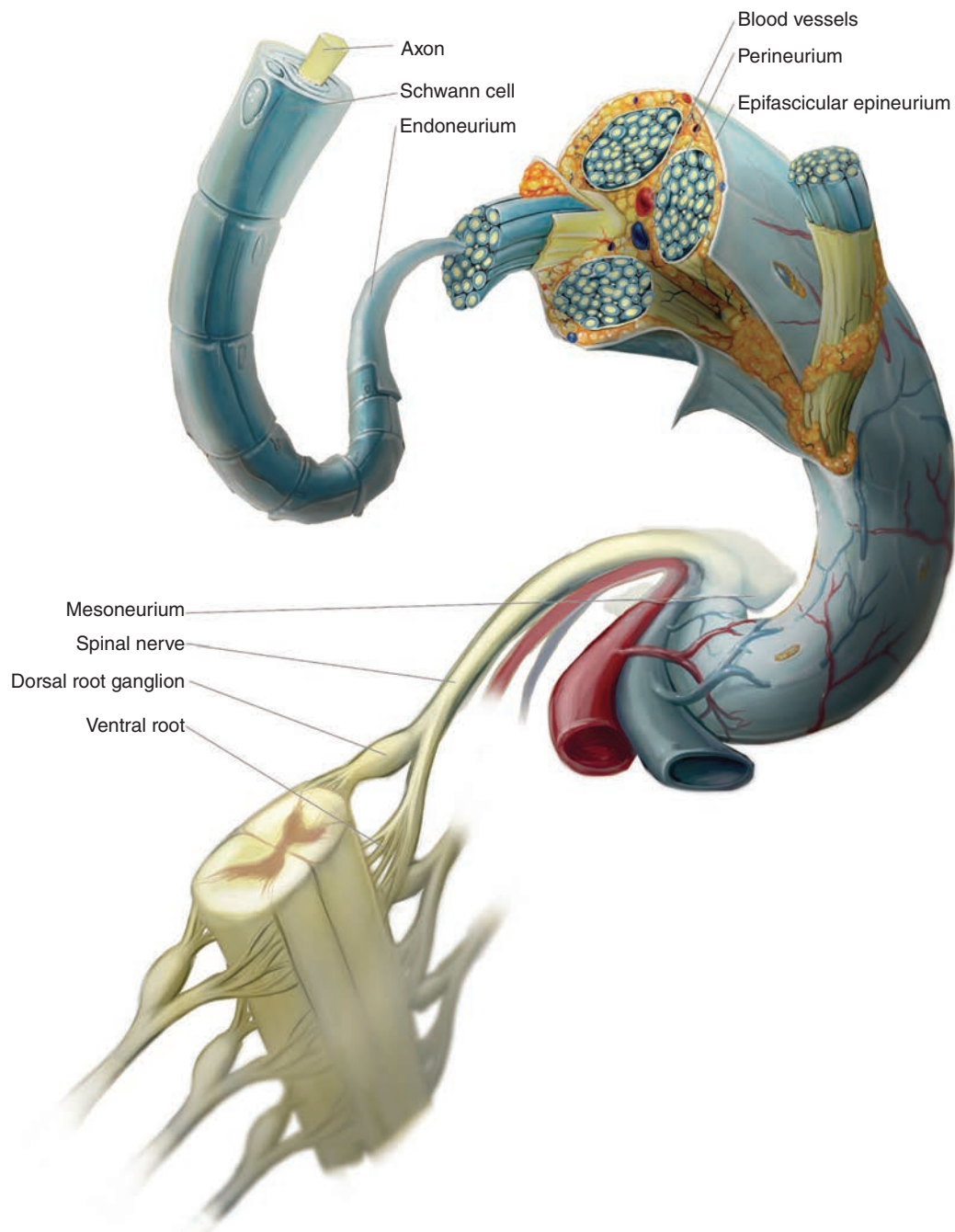


FIGURE 1-3. Organization of the peripheral nerve.

Peripheral nerves receive blood supply from the adjacent blood vessels running along their course. There are two independent interconnected vascular systems. The extrinsic system consists of arteries, arterioles, and veins that lie within the epineurium. The intrinsic vascular system comprises a

group of longitudinal capillaries that run within the fascicles and endoneurium. Neuronal injury after nerve blockade may be due, at least partly, to the pressure or stretch within connective sheaths and the consequent interference with the vascular supply to the nerve.

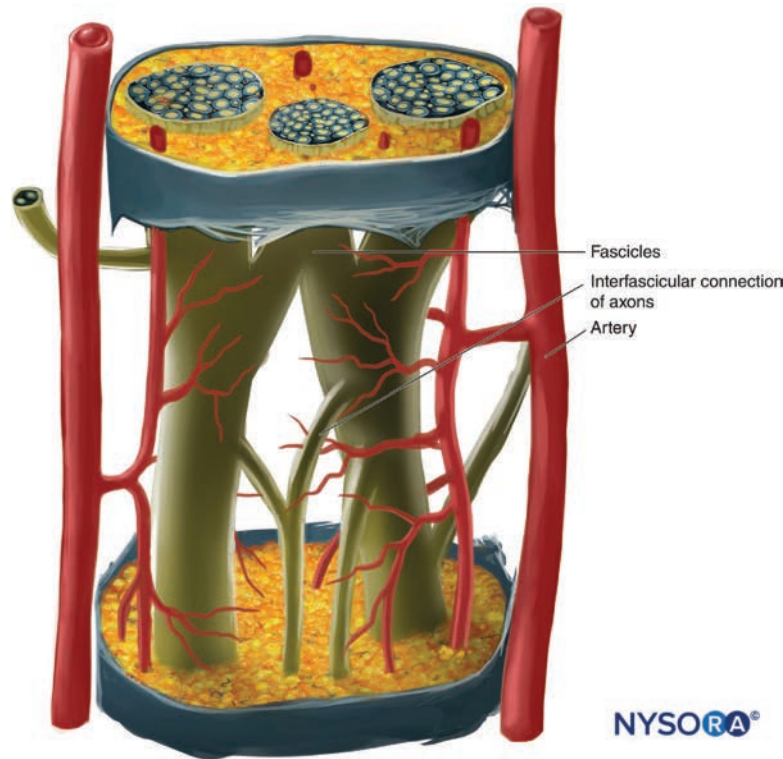


FIGURE 1-4. Diagram of fascicular arrangement in a peripheral nerve.

Communication Between the Central Nervous System and Peripheral Nervous Systems

The central nervous system (CNS) communicates with the body through spinal nerves, which have sensory and motor components (Figure 1-5). The sensory fibers arise from neurons in

the dorsal root ganglia and enter the dorsolateral aspect of the spinal cord to form the dorsal root. The motor fibers arise from neurons in the ventral horn of the spinal cord and pass through the ventrolateral aspect of the spinal cord to form the ventral root. The dorsal and ventral roots converge in the intervertebral foramen to form the spinal nerves, which then divide into dorsal and ventral rami. The dorsal rami innervate muscles,

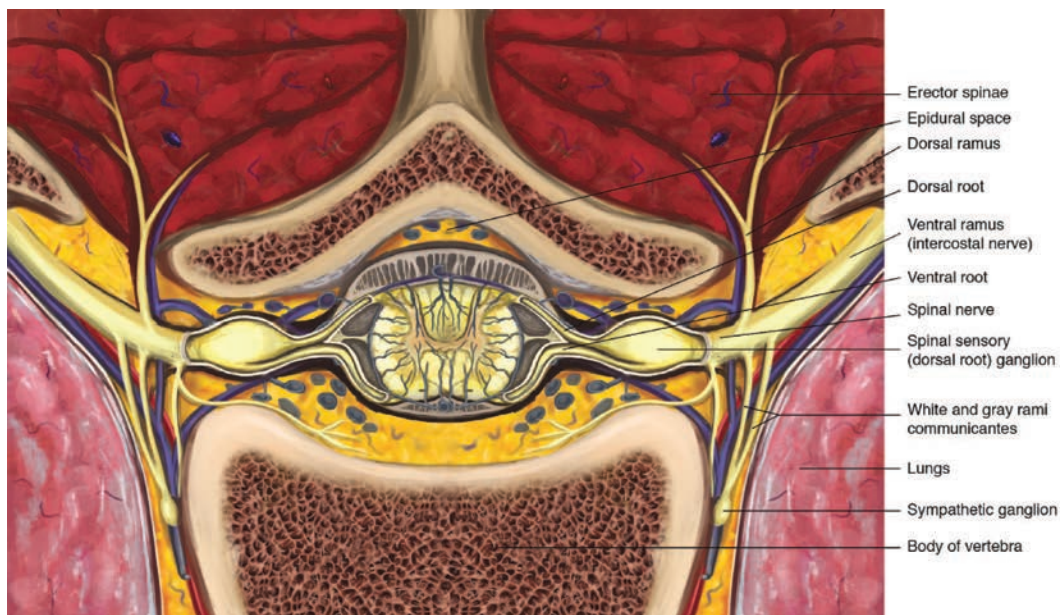


FIGURE 1-5. Schematic transverse section of thoracic vertebra showing the spine and the origin of spinal nerves.

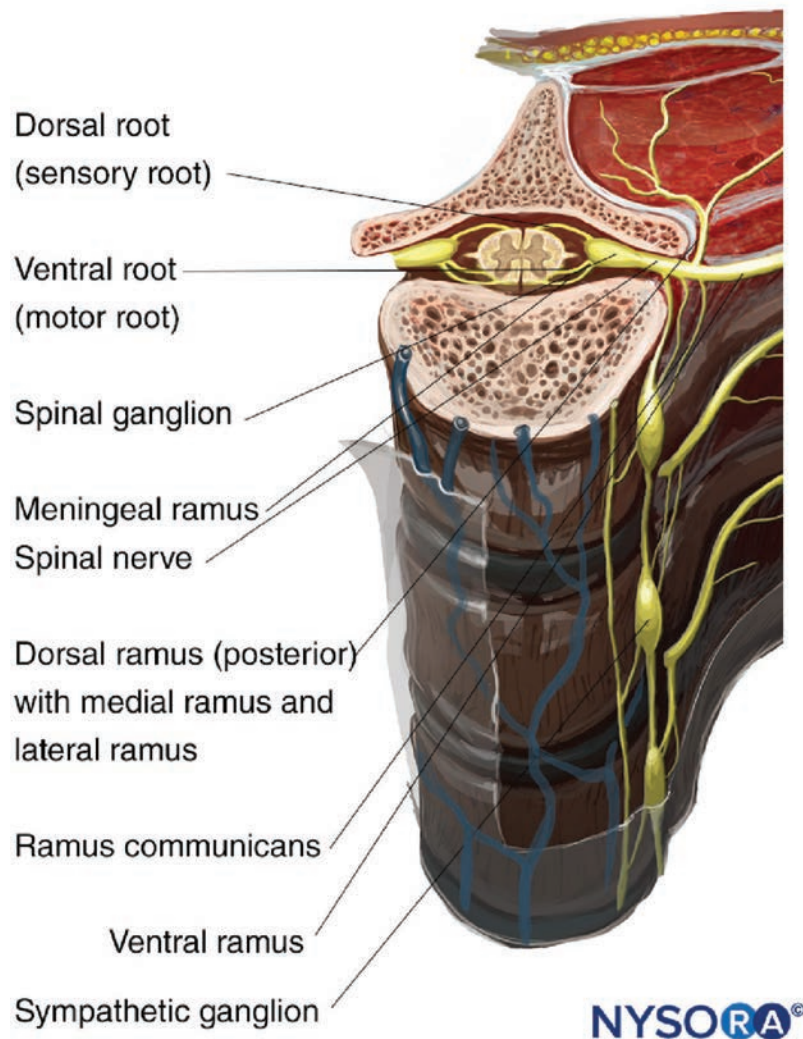


FIGURE 1-6. Anatomy of a typical spinal intercostal nerve.

bones, joints, and the skin of the back along the posterior midline. The ventral rami innervate muscles, bones, joints, and the skin of the antero-lateral aspect of the neck, thorax, abdomen, pelvis, and the extremities (Figure 1-6).

Spinal Nerves

There are 31 pairs of spinal nerves: 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 1 coccygeal. Spinal nerves pass through the vertebral column at the intervertebral foramina (Figure 1-7). The first cervical nerve (C1) passes superior to the C1 vertebra (atlas). The second cervical nerve (C2) passes between the C1 (atlas) and C2 (axis) vertebrae. This pattern continues down the cervical spine; however, because there

is no C8 vertebra, the C8 nerve passes between the C7 and T1 vertebrae.

In the thoracic region, the T1 nerve passes between the T1 and T2 vertebrae. This pattern continues down through the remainder of the spine. The vertebral arch of the fifth sacral and first coccygeal vertebrae is rudimentary. Because of this, the vertebral canal opens inferiorly at the sacral hiatus, where the fifth sacral and first coccygeal nerves pass. Roots of spinal nerves must descend through the vertebral canal before exiting the vertebral column through the appropriate intervertebral foramen since the inferior end of the spinal cord (conus medullaris) is located at the L1-L2 vertebral level in adults. Collectively, these roots are called the cauda equina.

Outside the vertebral column, ventral rami from cervical and lumbosacral spinal levels coalesce to form intricate

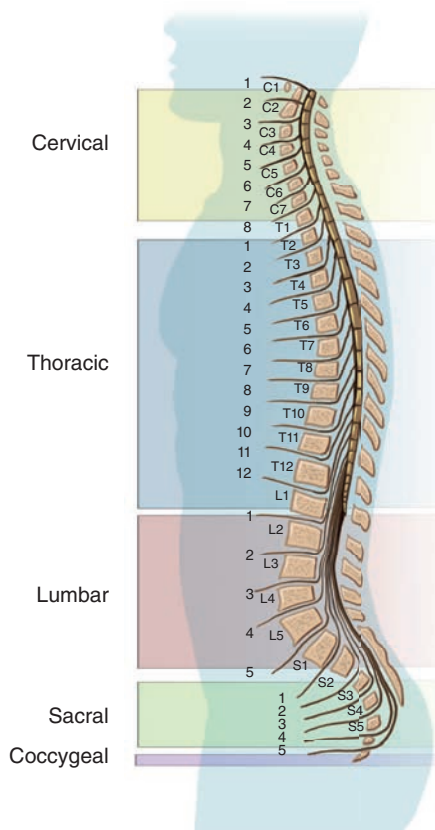


FIGURE 1-7. Spinal nerves.

networks called plexuses from which nerves extend into the neck, the arms, and the legs.

► Dermatomes, Myotomes, and Osteotomes

A **dermatome** is the area of the skin supplied by the dorsal (sensory) root of a specific spinal nerve (Figure 1-8). In the trunk, each segment is horizontally disposed, except C1, which does not have a sensory component. The dermatomes of the limbs from the fifth cervical to the first thoracic nerve (C5-T1) and from the third lumbar to the second sacral vertebrae (L3-S2) extend like a series of bands from the midline of the trunk posteriorly into the limbs. Of note, there is considerable overlapping between adjacent dermatomes.

A **myotome** is the segmental innervation of skeletal muscle by a ventral root of a specific spinal nerve (Figure 1-8). An **osteotome** is the area of the bone supplied by the sensory root of the specific spinal nerve.

Distribution of dermatomes, myotomes, and osteotomes does not follow the same pattern in some areas, where different nerves supply the innervation of deep and superficial structures (Figure 1-8). Regardless, the knowledge of their distribution is relevant for the application of regional anesthesia as a guide to decide which block techniques are appropriate to provide adequate analgesia and anesthesia for specific surgical procedures.

► Thoracic and Abdominal Wall Thoracic Wall

The intercostal nerves originate from the ventral rami of the first 11 thoracic spinal nerves (T1-T11). Each intercostal nerve becomes part of the neurovascular bundle of the rib and provides sensory and motor innervations (Figure 1-9).

Except for the first, each intercostal nerve gives off a lateral cutaneous branch that pierces the overlying muscle near the midaxillary line. This cutaneous nerve divides into anterior and posterior branches, which supply the adjacent skin. The intercostal nerves from the second to the sixth space reach the anterior thoracic wall and pierce the superficial fascia near the lateral border of the sternum and divide into medial and lateral cutaneous branches.

Most fibers of the anterior ramus of the first thoracic spinal nerve join the brachial plexus for distribution to the upper limb. The small first intercostal nerve is the lateral branch and supplies only the muscles of the intercostal space, not the overlying skin. In contrast, the lower five intercostal nerves abandon the intercostal space at the costal margin to supply the muscles and skin of the abdominal wall.

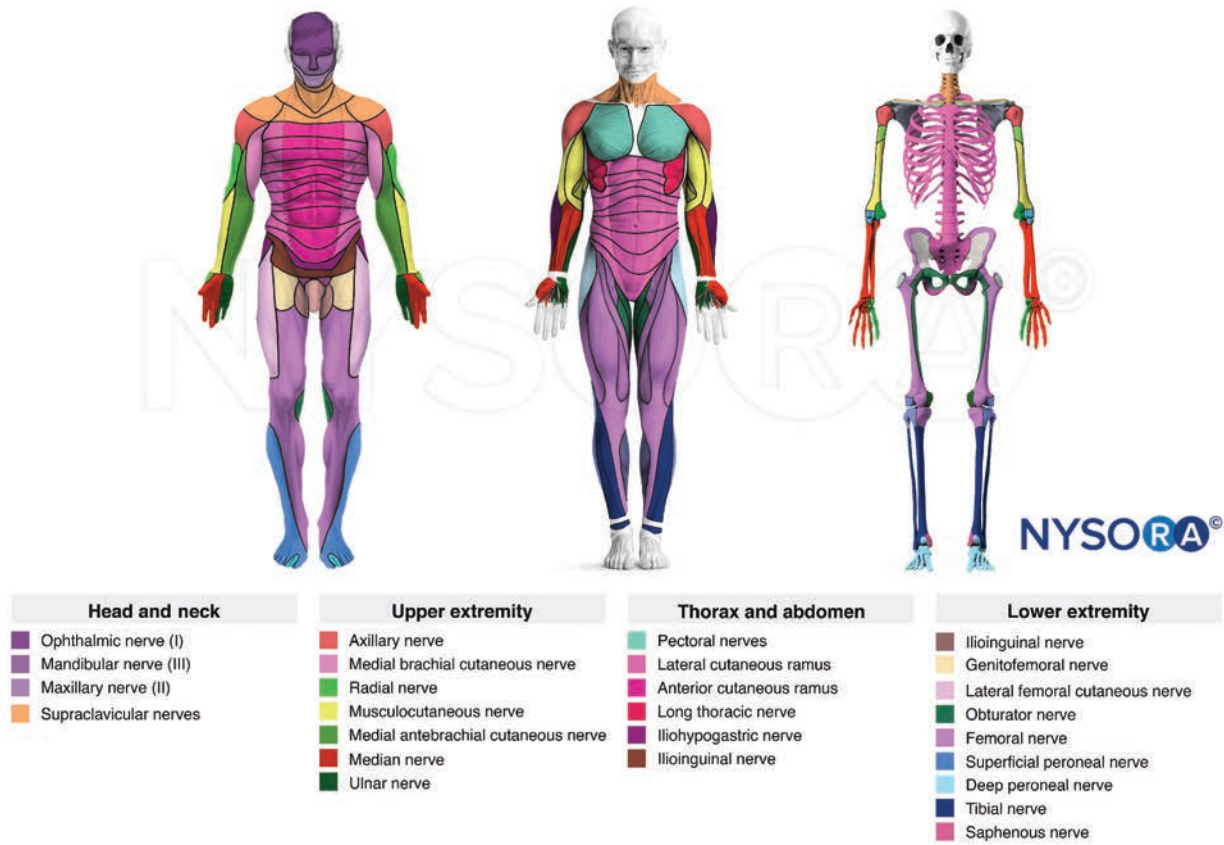
Anterior Abdominal Wall

The lower six thoracic nerves and the first lumbar nerve innervate the skin, muscles, and parietal peritoneum of the anterior abdominal wall. At the costal margin, the seventh to eleventh thoracic nerves (T7-T11) leave their intercostal spaces and enter the abdominal wall in a fascial plane between the transversus abdominis and internal oblique muscles. The seventh and eighth intercostal nerves slope upward following the contour of the costal margin, ninth runs horizontally, and the tenth and eleventh have a downward trajectory. Anteriorly, the nerves pierce the rectus abdominis muscle and the anterior layer of the rectus sheath to emerge as anterior cutaneous branches that supply the overlying skin (Figure 1-9).

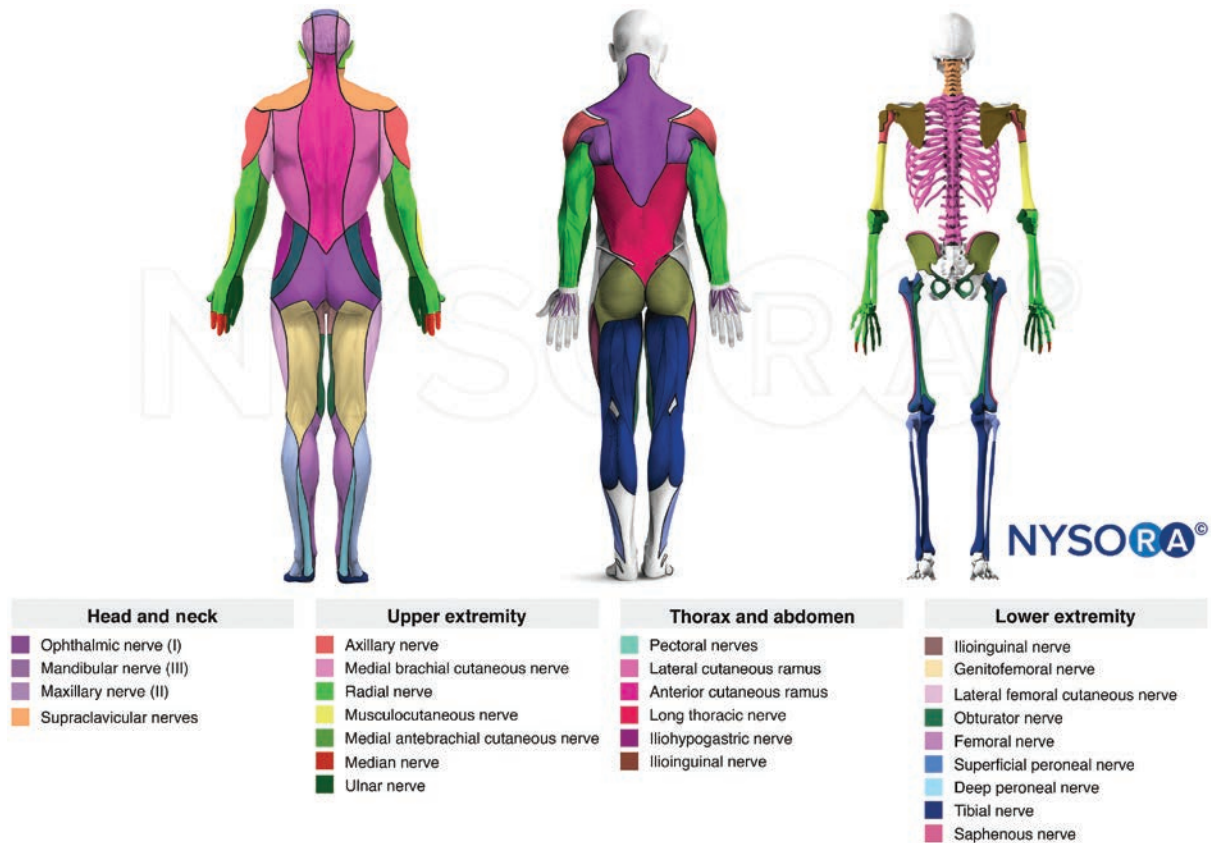
The subcostal nerve (T12) takes the line of the twelfth rib across the posterior abdominal wall. It continues around the flank and terminates similarly to the lower intercostal nerves. The seventh to twelfth thoracic nerves (T7-T12) give off lateral cutaneous nerves, which further divide into anterior and posterior branches. The anterior branches supply the skin as far forward as the lateral edge of the rectus abdominis. The posterior branches supply the skin overlying the latissimus dorsi. The lateral cutaneous branch of the subcostal nerve is distributed to the skin on the side of the buttock.

The iliohypogastric and ilioinguinal nerves, both branches of L1, supply the inferior part of the abdominal wall. The iliohypogastric nerve runs above the iliac crest and splits into two terminal branches. The lateral cutaneous branch supplies the side of the buttock; the anterior cutaneous branch supplies the suprapubic region.

The ilioinguinal nerve leaves the intermuscular plane by piercing the internal oblique muscle above the iliac crest. It continues between the two oblique muscles to enter the



A



B

FIGURE 1-8. Distribution of dermatomes, myotomes, and osteotomes: (A) anterior view and (B) posterior view.